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GB 0921400 A GB 0886204 A GB 0867944 A

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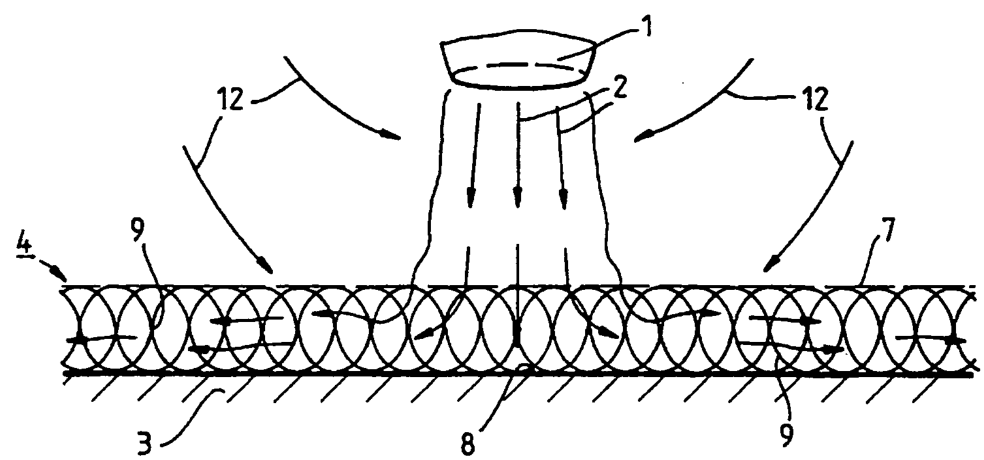
(54) **Landing mat for V/STOL aircraft.**

(57) A ground environment mat for VSTOL aircraft comprising a porous core element 9 having an upper surface 7 porous enough to permit jet entry and controlling the effect of laterally transmitted ground jets resulting therefrom to reduce hot gas and debris ingestion by the aircraft's air intakes, suck-down on the aircraft's surfaces and ground or deck erosion or heating. The porous core element may comprise mesh or strands, or twisted flat strips or metal tubes or perforated elements hingedly attached to a backing layer. There may be an impervious lower surface 8.

Fig.1b.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1a.

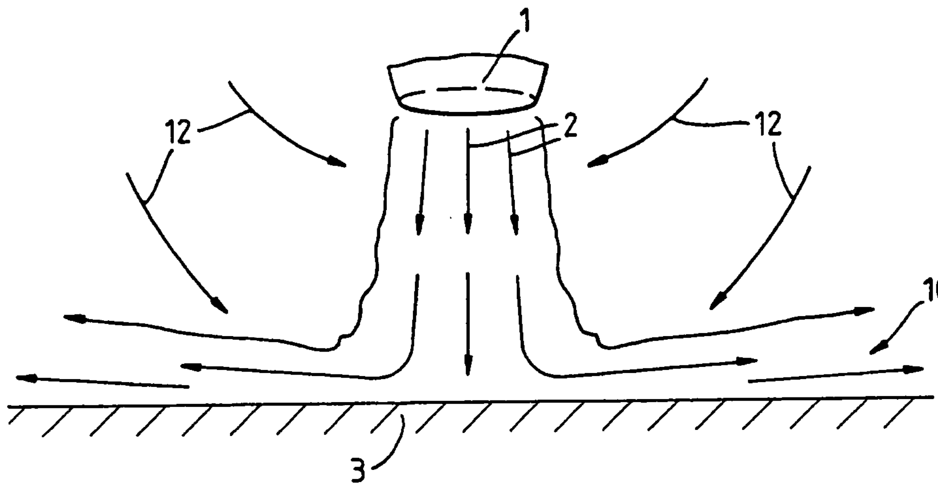


Fig.1b.

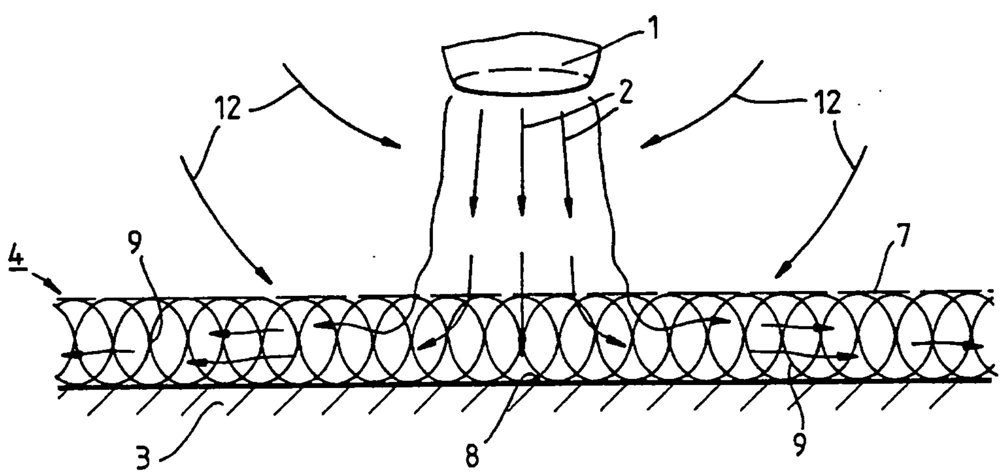


Fig. 2a.

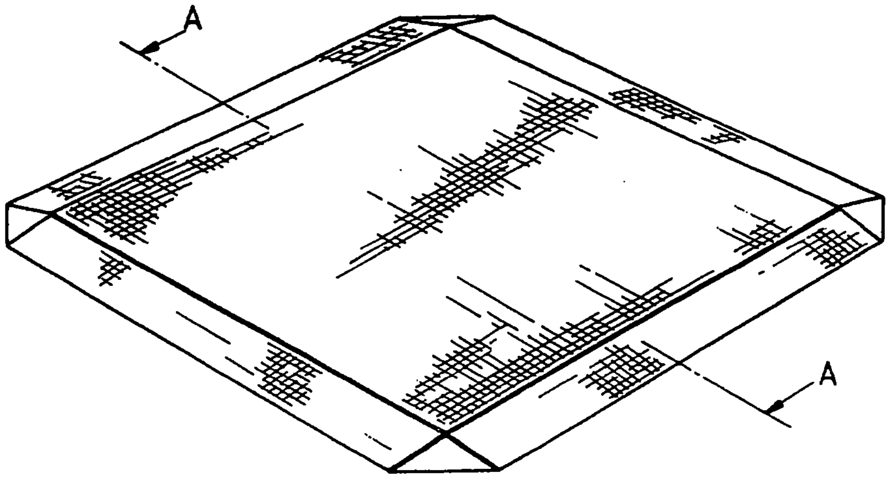


Fig. 2b.

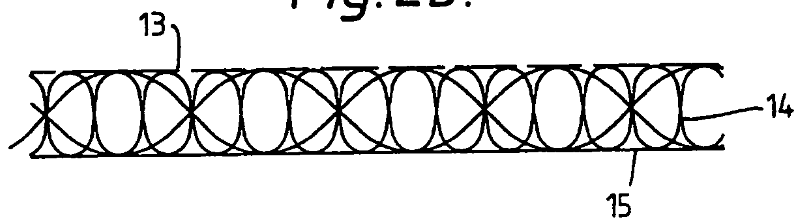


Fig. 2c.

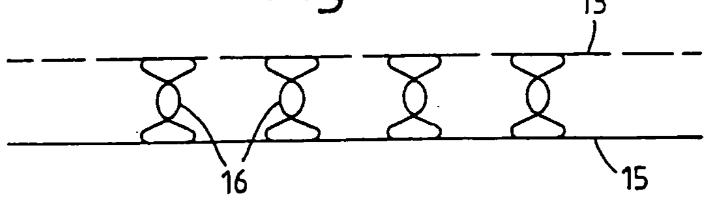


Fig.3a.

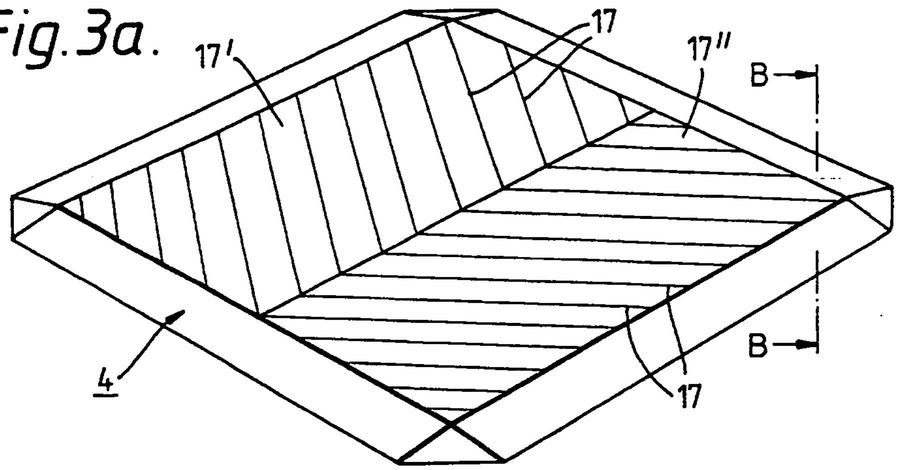


Fig.3b.

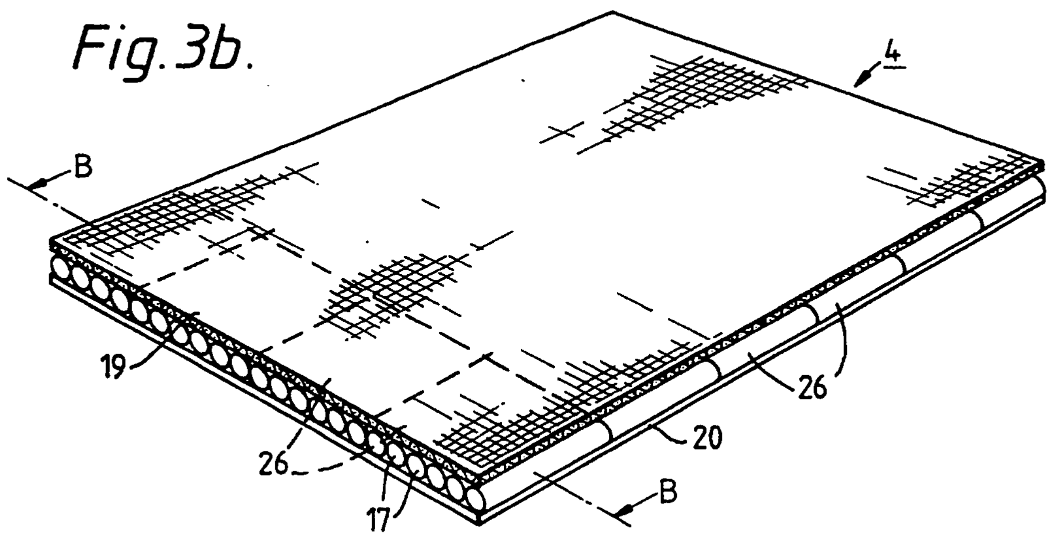


Fig.3c.

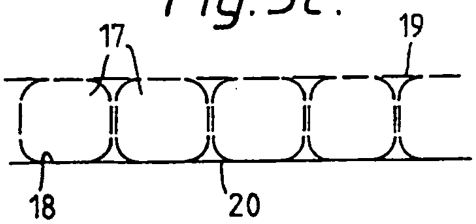


Fig.3d.

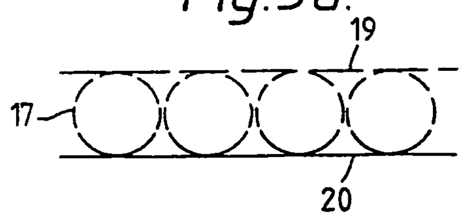


Fig.3f.

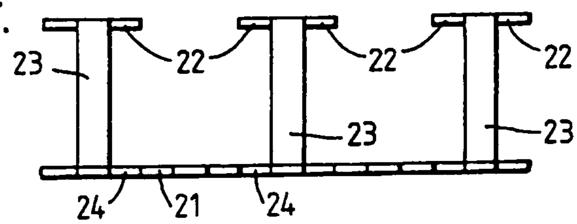


Fig.3e.

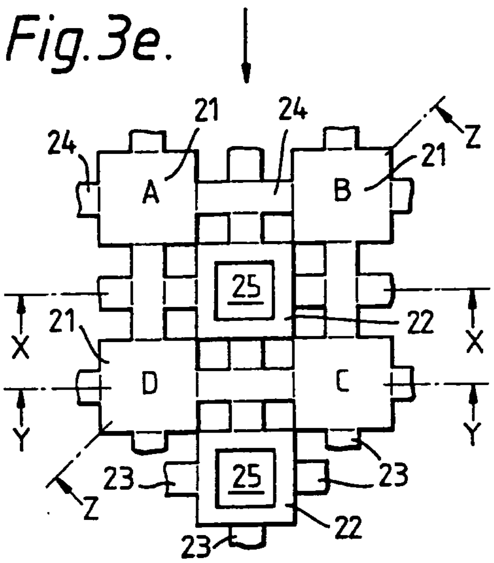


Fig.3g.

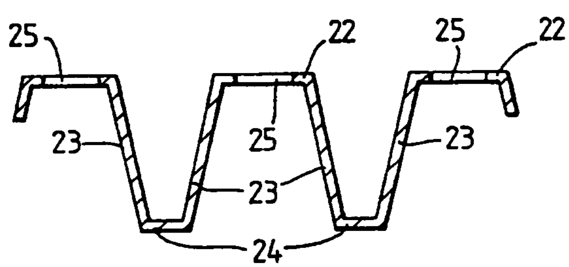


Fig.3h.

Fig.3i.

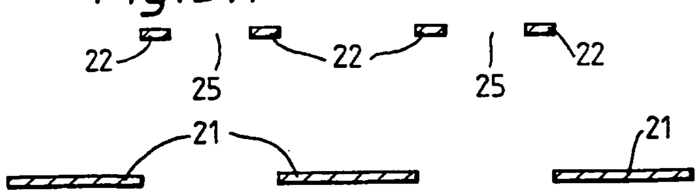


Fig.4a.

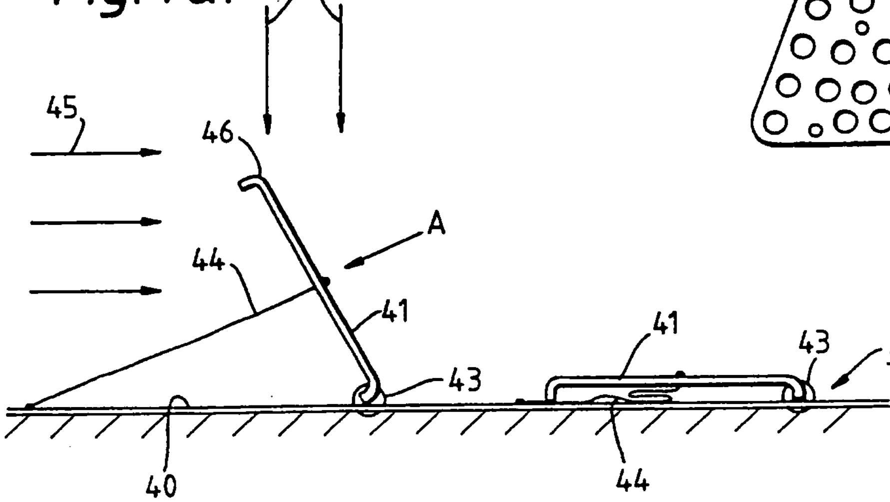


Fig.4b.

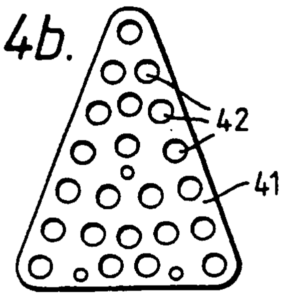


Fig.4c.

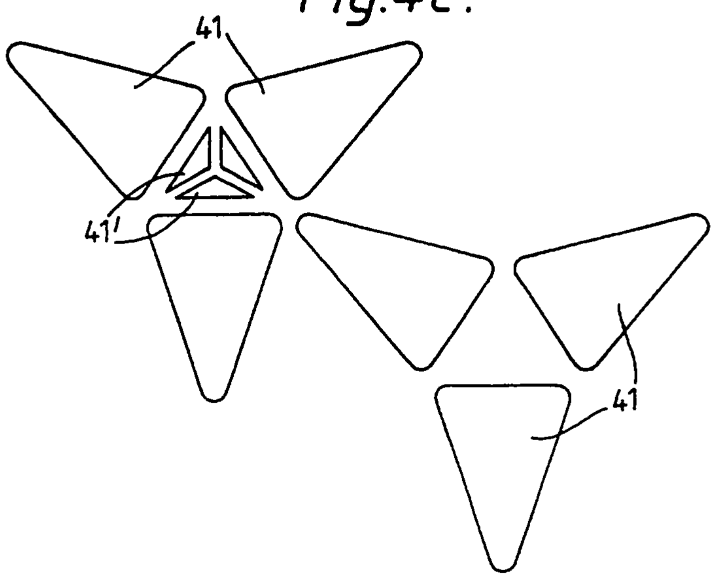
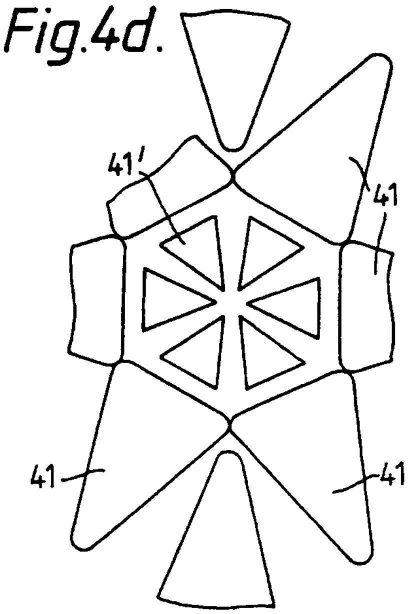


Fig.4d.



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GROUND ENVIRONMENT MATS

This invention relates to ground environment mats for vertical/short take-off and landing (VSTOL) aircraft operations and particularly, although not exclusively, to such ground environment mats for operations of VSTOL aircraft of the type which use one or more gas turbine engines for wing-borne flight and, by vectoring the engines exhaust efflux downwardly and/or by driving one or more fans which exhaust downwardly, for engine-borne flight.

During take off and landing, the hot gas efflux, which we will refer to hereinafter as the jet or jets, from the lifting engines or fans of a VSTOL aircraft strike the ground and produce complex fluid flows around the aircraft, often resulting in substantial and unfavourable aerodynamic and environmental effects on aircraft operations.

The effects caused by the interaction between the ground and the VSTOL aircraft's jets include:

1. Ground jet sheets
2. Fountain flows due to ground jet interaction where there are jets from two or more exhaust sources on the aircraft
3. Hot gas ingestion of the engine or fan exhaust by the air intakes
4. Downwash induced mainly by ground jet entrainment, on the aircraft's surfaces ("suck-down")
5. Ground or deck erosion and/or heating
6. Debris and dust ingestion into air intakes

7. Thermal and acoustic fatigue on the aircraft structure and equipment

Re-circulation of hot exhaust gases into the engine intakes can result in large thrust losses, or even compressor stall. Variations of aircraft lift due to downwash induced by ground jet entrainment also degrade VSTOL performance. The hot upwash flows and the sound pressure generated by the exhaust jets and their interaction with the ground may result in thermal and acoustic fatigue of the aircraft structure and equipment. Ground erosion due to the high temperature, high pressure jets, ingestion of debris thrown up by the ground impinging jets and the reduction in pilot visibility due to dust cloud creation are other major problems. These latter problems are exacerbated when the VSTOL aircraft is operating from non-permanent surfaces such as desert or natural terrain, whilst some of the problems above arise in ship-borne or more conventional operating environments.

To counter these problems it is known to use prefabricated aluminium sheeting to protect the ground surface during VSTOL aircraft operations on land. For ship-borne operations, an anti-skid surface known as "Camrex" is painted onto thick steel plate for protection of the ships decking against erosion and heat. These known protective measures are not designed to improve aircraft performance in terms of reduced hot gas ingestion, ground effect lift loss, and debris/dust ingestion.

The problems mentioned above will be further exacerbated by the introduction of VSTOL aircraft with high temperature, high pressure exhausts.

It is an object of the present invention to provide landing surfaces which will overcome the problems listed above.

It is a further object of the present invention to provide both permanent and portable devices which will overcome the problems listed above.

According to the present invention there is provided a ground environment mat comprising a porous core element having an upper surface porous enough to permit jet entry into the mat.

In use the ground environment mat is laid on the ground so that its upper surface will receive the jet or jets from a VSTOL aircraft taking off from or landing upon the mat. The upper surface of the mat allows the jet to reach the porous core element which slows the jet down and removes energy from it. The core element allows lateral flow of the jet throughout the mat to exhaust from the mat edges.

The ground environment mat is preferably constructed from material capable of withstanding the weight of the VSTOL aircraft before take-off and after landing.

Provided the ground on which the mat is located is impermeable the jet from the VSTOL aircraft will be diverted by the ground to travel laterally through the porous core element. Where the ground is a permeable, non-permanent, surface such as desert an alternative form of the mat is used.

In this case at least the mat additionally comprises a lower substantially impermeable surface.

The porous core element of the mat may comprises material of mesh or strand consistency. The mat may be made of a flexible light-weight material so that it is transportable.

The porous core element may comprise porous metal tubular, deep drawn, pressed or extruded metal sections.

The mat may comprise a plurality of mat elements each comprising an upper porous surface and a porous core element and demountably linked to neighbouring mat elements.

Embodiments of the invention will now be described by way of example only and with reference to the following drawings of which:

Figures 1a and 1b are schematic side elevation views of a VSTOL jet operating in a ground environment illustrating the principles of the invention; Figure 1a shows the jet/ground interaction without a ground environment mat and Figure 1b shows the jet/ground interaction with a ground environment mat in place;

Figures 2a to 2c illustrate light weight ground environment mats; Figure 2a is a perspective view of a light-weight ground environment mat; Figure 2b is a cross sectional view along the lines AA of Figure 2a, of one form of light-weight ground environment mat; and, Figure 2c is a cross sectional view along the lines AA of Figure 2a of an alternative form of light-weight ground environment mat;

Figures 3a to 3i illustrate non portable heavy-weight versions of ground environment mats; Figure 3a is a perspective view of one form of heavy-weight ground environment mat; Figure 3b is a perspective view of an alternative form of heavy-weight ground environment mat; Figure 3c is a cross section along the lines BB of Figures 3a or 3b; Figure 3d is a cross section of an alternative construction of mat along the lines BB of Figures 3a or 3b; Figure 3e is a plan view of a further form of heavy-weight ground environment mat; Figure 3f is a view along the arrow P of Figure 3e; and, Figures 3g, 3h and 3i are sectional views along the lines X-X, Y-Y and Z-Z respectively of Figure 3e; and,

Figures 4a to 4d illustrate collapsible forms of ground environment mats; Figure 4a is a sectioned side view of part of a ground environment mat; Figure 4b is a view in the direction of arrow A of Figure 4a of an element of a ground environment mat; Figure 4c is a plan view of part of one form of the ground environment mat shown in Figure 4a; and, Figure 4d is a plan view of part of a further form of the ground environment mat shown in Figure 4a.

In Figure 1a a downwardly directed exhaust nozzle 1 of a gas turbine engine or fan of a VSTOL aircraft (not shown) directs the gas turbine engine or fan exhaust efflux, or jet, 2 towards a ground surface 3 during vertical take-off or landing operations. The ground 3 diverts the jet 2 into radially expanding ground jets 10. The ground jets 10 have a velocity profile in a direction normal to the ground which is

zero at ground level, peaks to a high maximum at points close to the ground and decays to zero at higher levels. The jet 2 also entrains ambient air resulting in a downward ambient airflow 12.

The high pressure jet 2 may cause ground erosion and heating at its point of impact with the ground. The ground jets 10 may throw up dust and debris which may get into engine air intakes (not shown) and damage the engine. Where the aircraft is fitted with more than one nozzle 1 the ground jets 10 from each will collide giving rise to fountain flows which may collide with the underside of the aircraft causing damage as well as diverting part of the hot fountain flows along the underside into the air intakes resulting in hot gas ingestion. Hot gas ingestion can also be caused by the bouncy effect of the hot ground jets and by the lifting up of the ground jets in a headwind situation. The downwash produced by the entrained air 12 causes suckdown on the aircraft's surfaces in turn requiring greater thrust from the gas turbine engines or fans in order to keep the aircraft airborne.

Figure 1b illustrates the use of a ground environment mat to overcome some of the problems listed with reference to Figure 1a. In Figure 1b a ground environment mat 4 comprises of a permeable upper layer 7, an impermeable lower layer 8, and porous or mesh elements 9 sandwiched between the layers 7 and 8.

In operation when the exhaust jets 2 impinge on the mat 4, the development of the resulting ground jets 10 will be substantially retarded by the porous upper layer 7 and the

porous or mesh elements 9. The rapid loss of momentum in the ground jets 10 means that the jet velocities inside the mat will be significantly lower than those which would arise without the mat. The energetic, peaky ground jet velocity profile described with reference to Figure 1a is replaced by a more uniform jet velocity profile and a less energetic flow. This large reduction of the ground jet energy greatly reduces the downwash of ambient air 12 entrained into the jets, hence reducing the lift loss in ground proximity.

The impermeable nature of the lower surface 8 of the ground environment mat 4 prevents erosion of the surface of the ground below the mat and acts to contain the ground jets 10 within the mat. The upper surface 7 is sufficiently porous to allow the impinging jet 2 to pass through relatively unhindered, but extracts energy from it and helps to inhibit hot gases from escaping up into the region beneath the aircraft which is especially important near the aircraft air intakes. There is also the potential for a reduction in hot gas ingestion when using the mat due principally to three factors:-

1. Fountain flow, identified as a powerful potential HGI source, will be suppressed due to weaker ground jets 10 and the resistance due to the upper surface 7 of the mat 4.
2. Control of the hot jet flow path inside the mat by appropriate design of the interior elements of the mat (described in more detail below) to ensure that

hot gases do not rise towards the aircraft's intakes.

3. Heat absorption and dissipation properties of the mat components.

Dust and debris are suppressed owing to the much reduced flow velocities, both along the mat 4 and along the ground surface outside the perimeter of the mat.

We now describe three variants of the ground environment mat design; light-weight ground environment mats, for light-weight, transportable, temporary ground fixation use on land; heavy-weight ground environment mats, suitable for more permanent ground fixation applications for both land and ship-borne operations; and, collapsible mats.

In Figure 2a a light-weight ground environment mat comprises a mat of approximately 25 meters by 25 meters designed to capture jets from a VSTOL aircraft operating in the height range 0 - 10 meters.

One form of the internal structure of the mat of Figure 2a is shown in cross section in Figure 2b and comprises high-drag elements 14 for example of mesh or strands, fixed to an impermeable lower layer 15 and a permeable upper layer 13. The high-drag elements comprise a compressible and flexible mesh structure which can withstand the weight of an aircraft and aircraft ground personnel i.e. the mat structure can be compressed at the loading points and return to its original thickness and size as soon as the loads are removed.

In Figure 2c an alternative mat construction is shown comprising high-drag elements 16 consisting of twisted flat

strips of typically metallic or composite materials attached to the lower layer 15 and upper layer 13. These flat strips have a full twist each and are placed in a uniform distribution for example at roughly 100 millimetre centres but probably at least 10 millimetres. Twist in the strips adds stiffness and makes the drag elements more multi-directional to cope with different ground jet directions.

The mat, in either the form shown in Figure 2b or the form shown in Figure 2c, is made of heavy duty, temperature resistant materials. It is designed to be readily deployable and packable for storage or transport. Fixation points (not shown) are provided over the area of the mat to enable the mat to be secured to the ground in use by suitable means such as pins or bolts (not shown). If the mat is to be deployed by air-dropping, at remote sites fixation to the ground may be made automatic using explosive fittings.

Heavy-weight forms of ground environment mats are shown in Figure 3. In Figure 3a a heavy-weight ground environment mat 4 comprises a plurality of parallel heavy-duty metal tubular sections 17 arranged in two groups 17' and 17'' which intercept in "v" formation at a centre line 5 of the mat 4. As will be seen in Figure 3c which is a cross section on the line BB of Figure 3a the sections 17 have porous upper and side surfaces of the sections but impermeable lower surfaces 18. The side surfaces of the sections 17 may assist with the directional channelling of the hot gases. The sections 17 are mounted on a heavy-duty metal impermeable lower layer 20. In an alternative construction shown in cross section in Figure

3d cylindrical sections 17 are sandwiched between a heavy-duty porous metal upper layer 19 and the lower layer 20.

In Figure 3b an alternative heavy-weight form of ground environment mat is shown. The mat 4 again comprises a plurality of parallel heavy-duty metal tubular sections 17 but, unlike the arrangement of Figure 3a, these are arranged all, or substantially all, in one direction. The sections 17 are made up in rectangular modules 26 linked together to form a core element of the requisite mat dimensions. A porous top layer 19 comprising an expanded metal mesh is attached to the upper surface of the sections 17 and an impermeable lower layer 20 is attached to the underside of the sections 17. The tubes of the section 17 may be as shown in Figure 3c or in Figure 3d.

Many variations in the constructions shown are possible, for example the upper and/or lower layers 19 and 20 may be dispensed with, provided the metal tubular sections 17 are held together in their parallel configuration for example by bolts, belts or adhesive bonding.

The tubular sections 17 of Figures 3a, 3c and 3d serve a number of functions; as drag elements to suppress high velocity ground jets (10 in Figure 1), to channel the hot exhaust away from the aircraft particularly away from the vicinity of air intakes; to assist heat dissipation; and, to support the top layer 19 (when used) which can be made using a heavy-gauge porous steel sheet construction.

An alternative form of construction shown in Figures 3e to 3i includes a plain metallic, plastics or composite sheet

which is punched and drawn (or deep drawn) to create upper and lower square shaped elements 22 and 21 respectively linked by strip like armatures 23 and 24 respectively. The upper elements or caps 22 are porous in that each has a square hole 25 punched therein. The armatures or stringers 23 provide in use directional aerodynamic drag response. The pitch between elements and the dimensions of the mat are chosen to give strength and stability under aerodynamic and aircraft wheel footprint loads. The pitch must be small enough to make a practical platform for personnel to walk on. The armatures 23 may be vertical or inclined as shown and the angle of inclination may be determined by structural and aerodynamic design considerations allied to material properties.

The heavy-weight mats shown in Figures 3 may be made of a plurality of similar individual sections linked together to form a mat of the required overall dimensions. This modular form of construction also allows individual sections to be taken out for replacement or service. Moreover sections of different porosity can be arranged in patterns of directional or isotropic drag elements as required to optimise performance of the mat.

The heavy duty ground environment mats shown in Figure 3 may range in size from that of the light-weight ground environment mats shown in Figure 2 to structures significantly larger to permit multi-aircraft operations.

A ground environment mat in collapsible form is shown in Figures 4a to 4d. In this form the mat 4 comprises a substantially impermeable lower backing layer 40 on which are

hingedly mounted a plurality of light weight high drag elements 41. The drag elements may be any convenient shape. In our example they are triangular and have a plurality of holes 42 passing there through. Each triangular element 41 is hinged to the lower layer 40 by means of a cleat 43 and normally lies flat on the lower layer as shown in the right hand side of Figure 4a. When a VSTOL aircraft approaches the mat its downwardly directed jets impinge on the drag elements 41 and because of their profile cause them to pivot about their cleats 43 and assume an upright position exposing their radiused edges 46 to the downwardly directed jet flow 47 as shown in the left hand side of Figure 4a where they are restrained by ties 44. In this position, it will be appreciated, the elements 41 together constitute a porous core element through the holes 42 of which ground jets 45 may pass laterally in the advantageous manner described with reference to Figure 1b above.

The elements 41 may be arranged on the lower layer 40 in symmetrical sets of three, with the bases of the triangles forming a triangular pattern, and with elements of neighbouring sets interlaid between adjacent pairs of elements, as shown in Figure 4c. Smaller triangular drag elements 41′, with different drag properties, may then be similarly grouped within the triangular area formed by the bases of the larger elements 41. Alternatively, the triangular elements may be arranged on the lower layer 40 in symmetrical sets of six, with the bases of the triangles

forming hexagons, again with groups of smaller elements 41′ within those hexagons, as shown in Figure 4d.

It is anticipated that in use 30 to 50% of the triangular elements 41 will deploy in the jet flow 47, but all will lay flat before take-off or after landing to support the aircraft footprint, ground crew or vehicles.

For single military fighter aircraft vertical take-off or landing operations a minimum mat area of approximately 25 metres by 25 metres is envisaged although the bigger the mat the greater could be the pilot's freedom to manoeuvre the aircraft close to the ground without hazard. The smallest mat which can be envisaged is one which is not smaller than the planform area enclosed by straight lines joining the extremities of the main lifting devices of the aircraft.

The light-weight ground environment mats, heavy-weight ground environment mats and the collapsible ground environment mats should have a thickness in the region of 5 - 60 cm. The porosity of the core elements and the upper layers in the embodiments shown is critical to the ground environment mats performance. The porosity of the core elements is selected to be in the region of 70 - 99% and in any event high enough to avoid spill-over of the ground jets (see 10 in Figure 1) above the mat. The porosity of the upper layer should be at least 20%.

CLAIMS

1. A ground environment mat comprising a porous core element having an upper surface porous enough to permit jet entry.

2. A ground environment mat comprising a porous core element having a porous upper surface and a substantially impermeable lower surface.

3. A ground environment mat as claimed in Claim 1 or Claim 2 and wherein the porosity of the core element is in the range 70% to 99% and the porosity of the upper surface is at least 20%.

4. A ground environment mat as claimed in any one of the preceding claims and wherein the mat has a thickness in the range of 5 to 60 centimetres.

5. A ground environment mat as claimed in any one of the preceding claims and wherein the area of the mat is not less than the planform area enclosed by straight lines joining the extremities of the main lifting devices of an aircraft which will use the mat.

6. A ground environment mat as claimed in any one of the preceding claims and wherein the porous core element comprises a structure of mesh or strands.

7. A ground environment mat as claimed in any one of the preceding claims and wherein the porous core element comprises a plurality of spaced apart, twisted flat

strips extending from an upper surface of the mat to a lower surface thereof.

8. A ground environment mat as claimed in Claim 7 and wherein the paced apart strips are separated one from the other in a uniform distribution by at least 10 millimetres.

9. A ground environment mat as claimed in any one of Claims 1 to 5 and wherein the porous core element comprises a plurality of parallel metal tubular sections.

10. A ground environment mat as claimed in Claim 9 and wherein the tubular sections are cylindrical.

11. A ground environment mat as claimed in Claim 9 or Claim 10 and wherein the tubular sections have porous side surfaces.

12. A ground environment mat as claimed in any of Claims 9 to 11 and wherein tubular sections are arranged in two groups which intercept in "v" formation at a centre line of the mat.

13. A ground environment mat as claimed in any one of Claims 9 to 12 and wherein the tubular sections are mounted on a metal impermeable lower layer.

14. A ground environment mat as claimed in Claim 13 and wherein the tubular sections are sandwiched between a porous metal upper layer and the lower layer.

15. A ground environment mat as claimed in any one of Claims 9 to 12 and wherein the tubular sections are held together in their parallel configuration by bolts, belts or adhesive bonding.

16. A ground environment mat as claimed in claim 1 or claim 2 and which is formed from a single layer of material so as to consist of a near vertical array of spaced apart ligaments connecting substantially impermeable lower planar elements and similar upper elements.

17. A ground environment mat as claimed in claim 1 or claim 2 and wherein said porous core element comprises a plurality of drag elements hingedly attached to a planar backing layer.

18. A ground environment mat as claimed in claim 17 and wherein said drag elements are triangular planar elements each having a plurality of holes therein.

19. A ground environment mat as claimed in claim 17 or claim 18 and wherein said drag elements are arranged in symmetrical patterns on said backing layer.

20. A ground environment mat substantially as herein before described and with reference to Figures 2a and 2b, or Figures 2a and 2c, or Figures 3a and 3c, or Figures 3a and 3d, or Figures 3e to 3i, or Figures 4a,4b and 4c, or Figures 4a, 4b and 4d of the accompanying drawings.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)** -17-	Application number GB 9320491.5
Relevant Technical Fields (i) UK Cl (Ed.L) B7G - G7AX, G7C, G7F, G7X) (ii) Int Cl (Ed.5) B64F - 1/00, 1/26 E01C - 9/00	Search Examiner B F BAXTER Date of completion of Search 9 DECEMBER 93
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ON-LINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- 1-20

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E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2178381 A	(GENERAL DYNAMICS) whole document	1, 2
X	GB 1484997	(DUNLOP) whole document	1
X	GB 1207188	(VEREINIGTE FLUGTECHNISCHE) whole document	1
X	GB 0921400	(SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION MOTEURS D'AVIATION) whole document	1-3, 6
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